1973

PATENT SPECIFICATION

(11) 1339 542

DRAWINGS ATTACHED

(21) Application No. 13460/70 (22) Filed 20 March 1970

(23) Complete Specification filed 19 April 1971

(44) Complete Specification published 5 Dec. 1973

(51) International Classification F28F 3/08//B21D 22/04

(52) Index at acceptance

F4S 4B 4E 4G

B3A 158

B3E 10A2 10A5

B3Q 2A11 2A5 2A6 2Q

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(19) THE PATENT OFFICE LONDON

(54) IMPROVEMENTS IN OR RELATING TO PLATE HEAT EXCHANGERS

(71) We, THE A.P.V. COMPANY LIMITED, a British Company, of Manor Royal, Crawley, Sussex, England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to plate heat exchangers.

A plate heat exchanger, as the term is generally understood, comprises a pack of separable generally rectangular plates arranged in spaced face-to-face relationship. A port, which is normally circular, is arranged adjacent each corner of each plate. Corresponding ports are aligned through the pack of plates, and the aligned ports constitute inlet and outlet ducts for each of two, usually liquid, heat exchange media which flow through alternate flow spaces defined between adjacent plates. Gaskets are arranged in or on the plates to define the flow spaces and to control the flow of media to them and to prevent leakage of the media. In use, the pack of plates is clamped together. Normally, flow of one liquid medium takes place from one of the bottom corner ports to one of the top corner ports of alternate flow spaces, while flow of the other liquid medium takes place downwards from the other of the top corner ports to the other of the bottom corner ports in the adjacent or intervening flow spaces. Because of the difference of the gasketting in each of the two types of plate, they are referred to as being of opposite hands, i.e. left hand and right-hand.

If the temperature rise of one medium is θ and the log mean temperature difference measured across the plate between the two liquid media is ΔT, then the thermal performance of the plate can be expressed as the ratio:

$$\frac{\theta}{\Delta T}$$

which is known as the temperature ratio (T.R.) of the plate.

The specification of the magnitude of this ratio represents quantitatively the thermal duty to be performed by the heat exchanger, while the temperature ratio which can in practice be achieved by any particular plate is given by the following relationship:—

$$\frac{2UA}{qC}$$

where

U = the overall heat transfer coefficient

A = the developed heat transfer surface area of the plate

q = the mass flow rate of either liquid medium across the plate

C = the specific heat of this liquid medium.

It will therefore be seen that the higher the heat transfer coefficient for any particular liquid the higher will be the temperature ratio which the plate can achieve.

One important factor in determining the magnitude of the heat transfer coefficient of a plate is the type of corrugation (trough form) or protuberance which is pressed into the plate, as this determines the amount of turbulence generated in the liquid medium, the generation of turbulence having as its object an increase in the heat transfer. The highest temperature ratio will be obtained at the minimum liquid flow rate at which the flow space will properly fill with liquid, while the minimum temperature ratio is given by the maximum liquid flow rate which can be achieved before the pressure loss across the flow space becomes excessive. The ratio of

the maximum to minimum temperature ratios corresponding to these two extreme conditions is relatively low (about 1.5:1 to 2:1) so that one plate design cannot be used over a wide range of temperature ratios corresponding with a wide range of thermal duties.

It is therefore necessary to provide plates with a number of different trough forms or shape of protuberance, each with its own values of heat transfer coefficient and therefore of temperature ratio. However, because the plate is an extremely complex pressing the tools for its manufacture are correspondingly expensive and to have one set of press tools for each range of temperature ratios required is uneconomic.

It is an object of the invention to provide a heat exchanger plate which can be produced in a variety of forms without the need for a complete set of press tools for each form.

According to the invention, a heat exchanger plate of the ported and gasketed type comprises a flow space area comprising end zones i.e. zones adjacent a fluid inlet and outlet respectively and a principal heat exchange area, at least the heat exchange area being formed with corrugations or other turbulence inducing formations, the said heat exchange area being formed as a plurality of discrete zones each having a pattern of corrugations or other formations thereon, at least one of the said discrete zones having a pattern which differs in respect of the turbulence inducing characteristics of the corrugations or other formations from that of at least one other zone, whereby the heat transfer characteristics of the zones of the plate differ between the said one discrete zone and the said discrete zone.

The zones will normally be divided into two groups; namely those with a pattern leading to a high temperature ratio, and those with a pattern leading to a low temperature ratio. The choice of the relative number of zones in said groups will be dictated by the duty to be performed.

A set of press tools for manufacturing plates of a variety of performances could thus consist of common parts for pressing the end areas including the ports and the zones connecting the ports with the main flow space area. There would also be two (or more if required) sets of partial tools for pressing the pattern for corrugations or other formations on the zones of the main flow space area. The invention also consists in a set of tools for pressing a range of heat exchanger plates having a flow space area comprising end zones, and a principal heat exchange area formed as a plurality of discrete zones each having a pattern of corrugations or other turbulence inducing formations, comprising common parts for pressing end areas of the plates including the said end zones, and two or more sets of partial tools for pressing the patterns of corrugations or other formations as the said discrete zones of the flow space area, the said sets being adapted to press patterns which differ in respect of the turbulence inducing characteristics of the corrugations or other formations, and also being interchangeable whereby plates may be pressed with either a complete set or with a composite set of partial tools made up from more than one of said sets.

The plates could be divided into zones along generally transverse (horizontal) lines, which may be straight or, preferably, broken to avoid lines of weakness across the plate. The breaking of the line could be achieved by introducing undulations therealong. Division along longitudinal (vertical) lines, straight or broken, is also possible.

The invention still further consists in a plate heat exchanger comprising a pack of plates with at least some of the plates arranged in spaced face-to-face relationship, with at least some of the plates being according to the invention as set forth above.

The invention will be further described with reference to the diagrammatic drawings accompanying the Provisional Specification and the accompanying diagrammatic drawings:

In the drawings accompanying the Provisional Specification:

Figures 1 and 2 are elevations of the plates of one type of conventional plate pair;

Figures 3 and 4 and Figures 5 and 6 are each elevations of the plates of two basic forms of pair from which the plates according to the invention are derived;

Figures 7 and 8 are elevations of the plates of one type of plate pair, incorporating the invention;

Figures 9 and 10 show a variation of Figures 3 and 4;

Figure 11 is an elevation of a further form of plate according to the invention;

Figures 12 and 13 are alternative partial longitudinal sections of Figure 11;

Figure 14 is a longitudinal section of a further form of plate according to the invention;

Figure 15 is an elevation of the plate of Figure 14;

Figures 16 and 17 show further possible variations of Figure 3;

Figures 18 and 19 are exploded side and end elevations of a pair of bolsters for a tool for pressing various types of plates according to the invention.

Figure 20 is a plan view of one bolster with the press tools in position; and

Figure 21 is a transverse section through the bolster and one press tool.

In the accompanying drawings:

Figures 22 and 23 are elevations of the

plates of another type of plate pair incorporating the invention; and

Figures 24 and 25 are elevations of a still further form of plate pair incorporating the invention.

A well-known form of plate design on which plate heat exchangers are based includes a flow space area with a series of parallel troughs 1 (see Figures 1 and 2) which are pressed into the plate and inclined at an angle to the vertical (longitudinal) axis of the plate. The adjacent plate has similar troughs 2 inclined at the same angle to the vertical axis but in the opposite direction. The two hands of the plate are illustrated in Figures 1 and 2, where Figure 1 shows the right hand and Figure 2 the left hand plate.

When the adjacent plates are clamped together the troughs run across one another so that contact occurs where the line of the top of one trough intersects the line of the bottom of the other trough, and by this means correct spacing between the plates is maintained.

The same principle of mutual support is achieved if the heat exchange area of flow space of the plate is divided up laterally into a number of horizontal bands 3, in which the angle of the trough with respect to the horizontal is reversed in each alternate band (see Figures 3 and 4). [redacted] ~~It is known that as an angle between the trough and the lateral directions (horizontal) is increased the value of the temperature ratio decreases, so that a plate with troughs at an angle of 60° (as illustrated in Figures 5 and 6) to the horizontal for example would give a much lower temperature ratio than the plates already described.~~ To achieve intermediate temperature ratios it would be necessary to have a trough angle of, for example, 45° and this would necessitate another set of press tools to produce this angle which would represent an undesirable item of capital expenditure.

It will be observed that each of the high temperature ratio plates illustrated in Figures 3 and 4 has five horizontal bands of 30° angle; these bands being designated 'A'. Likewise, it will be observed that the low temperature plates illustrated in Figures 5 and 6 have five horizontal bands 4 of 60° angle; these bands being designated 'B'.

It will be clear that a plate of a temperature ratio performance somewhere between that represented by the high temperature ratio plate embodying five 'A' bands and that separated by the low temperature ratio plate embodying five 'B' bands can be made up by a plate which consists of a mixture of 'A' bands and 'B' bands.

It will be seen that the plate of Figures 3 to 6, and also those of Figures 7 to 17 and 22 to 25, all have triangular zones at the ends of the flow space zone which are primarily distribution zones, although there is necessarily some heat exchange in these zones.

Another method of altering the heat transfer performance is by adjusting the pitch of the corrugations either alone or in combination with a change in angle.

A pair of plates illustrated in Figures 7 and 8 illustrate a trough pattern which consists of two 'B' bands and three 'A' bands. Any combination of 'A' and 'B' bands within the total number of five could be chosen according to the order of the temperature ratio (T.R.) required. There is, of course, no reason why the total number of bands should be limited to five it could be larger or smaller; the larger the number of bands the greater is the degree of flexibility in terms of temperature ratio which can be achieved, but the greater the number of press tool parts required.

For further variation in the temperature ratio of the plate one or other of the A or B bands could be substituted by a third band of a different trough angle and this could be repeated if necessary on additional bands. Another variant would be to make two or more bands into a single unit which in certain circumstances might simplify the tool making problem. It must be appreciated though that the more of these single unit bands that are made the fewer are the number of basic A and B bands that can be utilised from the original tool to give an alternative value of temperature ratio.

The press tool for the plates of Figures 3 to 8 would be constructed in such a way that the sections of the tool corresponding to the 'A' and 'B' bands were interchangeable so that a single composite tool could produce plates with these various trough combinations according to the temperature ratio requirements.

It will be observed that the gasket arrangement in the plates illustrated in Figures 7 and 8 is such that the flow takes place between ports located in diagonally opposite corners of the plate. An alternative arrangement is one in which the flows is more nearly parallel to the side of the plate and runs between the two ports adjacent to a side of the plate. This arrangement has the advantage that by inverting the plate through 180° in a vertical plane it provides a plate of the opposite hand so that only one set of press tools to form the trough is required to produce both hands of the plate.

It will be observed that in the plates illustrated in Figures 7 and 8 the types of bands are arranged in the same sequence. This means that when two plates are clamped together A bands are opposite A bands and B bands opposite B bands and there will be

five changes in flow passage along the plate. It is possible to assemble the bands in a different order for the plates in Figure 8 from that of the plate of Figure 7, and by substitution of an A band by a B band in Figure 8 re-arrangement of the resulting three bands and two A bands would give a flow passage in which each A band of either plate is opposed by B and in the adjacent plate so that a common flow passage would be achieved along the plate.

If this plate is fitted with an even number of trough bands this arrangement has the advantage that by inverting the plate through 180° in a vertical plane it provides a plate of the opposite hand by giving both alternate port positions and troughs which cross over one another on adjacent plates.

In the case of inversion of the trough pattern, the sequence of the band determines the nature of the flow passage. A sequence of A B A B has as its inversion B A B A so that in all parts of the plate A and B bands are opposed and a common flow passage results. A sequence A B B A when inverted will give A B B A so that the flow passage at the end of the plate will be different from that at the middle. A sequence A A A B with its inversion B A A A will give a further variant.

Figures 9 and 10 illustrate a right and left hand plate based on this principal with four horizontal bands and it will be seen that the inverted trough pattern of Figure 9 when inverted becomes the trough pattern of Figure 10. Hence the principle of the two types of band 'A' and 'B' with the combination of bands in the manner already referred to, will enable a number of plates of varying temperature ratios to be produced but instead of having one set of trough pressing tools for each hand of plate of a single set of tools having replaceable sections corresponding to 'A' and 'B' will enable both hands to be manufactured.

Figures 24 and 25 illustrate the use of non-handed plates with A B A B and B A B A configurations.

It will be appreciated that in a sample and practicable case, the number of zones in a plate may be two, one of type 'A' and the other of type 'B'. These could be arranged so that alternate plates were essentially inverted so that 'A' and 'B' cooperate throughout a pack of plates.

It is possible to apply the principle of interchangeable bands or sections to other forms of troughs besides the oblique type which has so far been illustrated. Another common form of trough runs transversely across the plate at right angles to the vertical axis and intermates with the trough of the adjacent plate. The depth of the trough may be greater than the pitch of the plates. In this case the heat transfer coefficient depends on the pitch and angle of the trough and a plate of this type is illustrated in Figure 11, where it is shown divided into four bands 'A', 'B', 'A', 'B', in which the variation between the trough shown in each type of band would be either the depth, as shown in Figure 12, or the pitch, as shown in Figure 13, or could be both.

Another turbulence promoting plate formation consists of a number of dimples 5, usually circular, which are pressed into the plate as shown in Figure 14. The heat transfer coefficient depends on the pitch and size of the dimples 5, and the 'A' band could, for example, consist of small diameter closely pitched dimples while the 'B' band could consist of large diameter widely pitched dimples so that plate consisting of either 'A' bands or 'B' bands or a combination of the two as shown in Figure 15 could be produced to give a varying range of temperature ratios.

This principle could be applied to other forms of turbulence promoting formations used in plate heat exchangers.

Referring once again to the construction shown in Figures 3 to 10 and 24 and 25, it will be observed that the horizontal line coinciding with the junction between any two bands represents a plane of weakness with respect to horizontal bending of the plate. This can be avoided if this line is broken by the overlapping or intermating of two adjacent bands, two examples being shown in Figures 16 and 17. In Figure 16, the bands meet on an undulating line 6, while in Figure 17 the bands meet on a castellated or square wave form undulating line 7.

Figures 18 to 21 illustrate a form of tooling which may be employed for producing the types of plates shown in Figures 3 to 8.

The tool consists of two opposed bolster 10 and 11 each having a recess 12 for receiving a set of tool sections. As illustrated, th set of tool sections comprises two end too sections 13 and five main sections. Of thes two are sections 14 with steeply inclined cor rugations and the other three sections 1 have less steeply inclined corrugations. Th sections 14 and 15 are interchangeable an any selection of them may be used whereb a large number of variations in the plate may be achieved. The number is not nece sarily limited to five, but any suitable num ber of sections may be chosen.

The foregoing system which has been co fined to bands which divide the plate hor zontally can also be applied to bands whic divide the plate vertically, as shown in Figur 22 and 23, or a combination of the tw systems whereby the plates are divided hor zontally and vertically into a number of re tangular elements which provide interchang able sections of the press tool to give t maximum flexibility and variation in the te perature ratio of the plate. The general

vertical bounding lines of the bands can be straight as illustrated in Figures 22 and 23, or they may be undulated or castellated as described with reference to Figures 16 and 17.

WHAT WE CLAIM IS:—

1. A heat exchanger plate of the ported and gasketed type comprising a flow space area comprising end zones i.e. zones adjacent a fluid inlet and outlet respectively and a principal heat exchange area, at least the principle heat exchange area being formed with corrugations or other turbulence inducing formations, the said heat exchange area being formed as a plurality of discrete zones each having a pattern of corrugations or other formations thereon, at least one of the said discrete zones having a pattern which differs in respect of the turbulence inducing characteristics of the corrugations or other formations from that of at least one other zone, whereby the heat transfer characteristics of the zones of the plate differ between the said one discrete zone and the said other discrete zone.

2. A heat exchanger plate as claimed in claim 1, in which the discrete zones are in two groups, with the zones of one group having a pattern tending to higher temperature ratio characteristics (as hereinbefore defined) than the pattern of the plates in the other group.

3. A heat exchanger plate as claimed in claim 1 or 2, in which the said discrete zones have corrugations inclined to the general direction of flow, with the variation of heat transfer characteristics being achieved by difference in the angle of inclination, and/or in the pitch of the corrugations.

4. A heat exchanger plate as claimed in any of claims 1 to 3, and in which the number of the said discrete zones is even and the sequence of the zones is selected so that when alternating with an adjacent inverted plate a particular form of flow passage is achieved.

5. A heat exchanger plate as claimed in claim 1 or 2, in which the said discrete zones have transverse corrugations and the variation in heat transfer characteristics is obtained by varying the depth and/or pitch of the corrugations.

6. A heat exchanger plate as claimed in claim 1 or 2, in which the said discrete zones have turbulence promoting dimples, and in which the variation in heat transfer characteristics is achieved by variation in the size and/or spacing the dimples.

7. A heat exchanger plate as claimed in any of claims 1 to 6, in which the boundary line between adjacent ones of the said discrete zones is straight.

8. A heat exchanger plate as claimed in any of claims 1 to 6, in which the boundary line between adjacent ones of the said discrete zones is undulating.

9. A set of tools for pressing a range of heat exchanger plates having a flow space area comprising end zones, i.e. zones adjacent a fluid inlet and outlet respectively and a principal heat exchange area formed as a plurality of discrete zones each having a pattern of corrugations or other turbulence inducing formations, comprising common parts for pressing end areas of the plates including the said end zones, and two or more sets of partial tools for pressing the patterns of corrugations or other formations on the said discrete zones of the flow space area, the said sets being adapted to press patterns which differ in respect of the turbulence inducing characteristics of the corrugations or other formations and also being interchangeable whereby plates may be pressed with either a complete set or with a composite set of partial tools made up from more than one of the said sets.

10. A heat exchanger plate pressed from a set of tools as claimed in claim 9.

11. A heat exchanger comprising a pack of plates arranged in spaced face-to-face relationship, in which at least some of the plates are plates as claimed in any of claims 1 to 8 or 10.

12. A heat exchanger plate substantially as hereinbefore described with reference to any of Figures 5 to 17 of the drawings accompanying the Provisional Specification.

13. A heat exchanger plate substantially as hereinbefore described with reference to any of the Figures of the accompanying drawings.

14. A set of tools for pressing heat exchanger plates substantially as hereinbefore described with reference to Figures 18 to 21 of the drawings accompanying the Provisional Specification.

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Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1973.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

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1339542 PROVISIONAL SPECIFICATION

5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

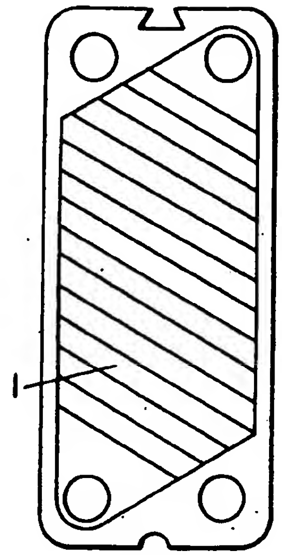


FIG.1.

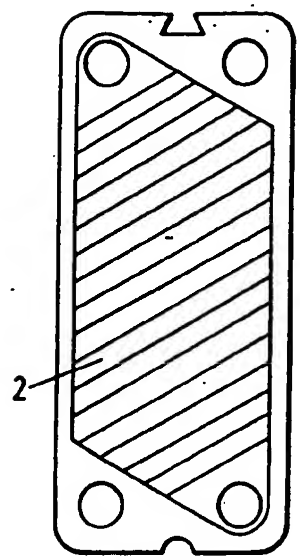


FIG.2.

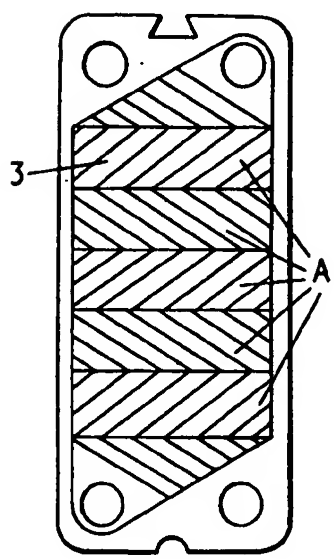


FIG.3.

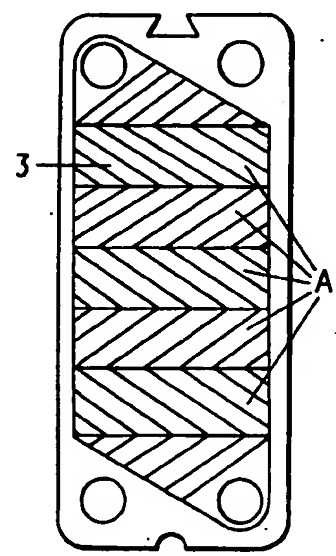


FIG.4.

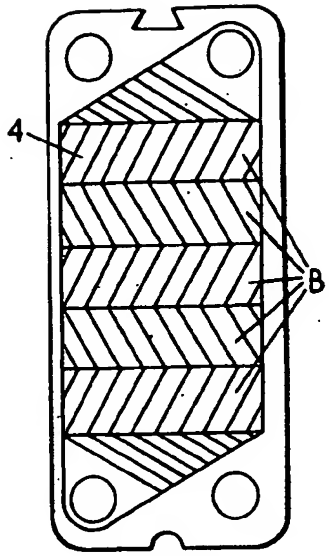


FIG.5.

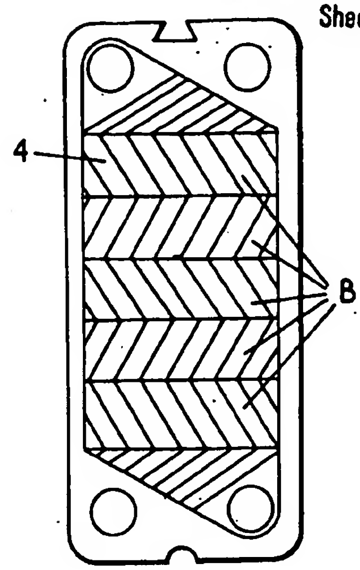


FIG.6.

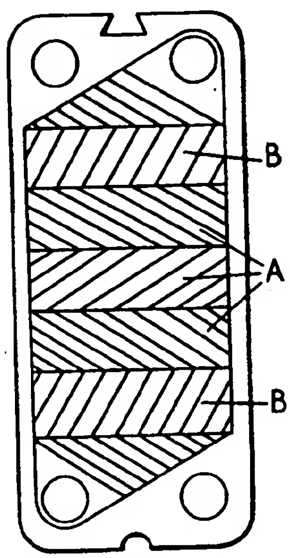


FIG.7.

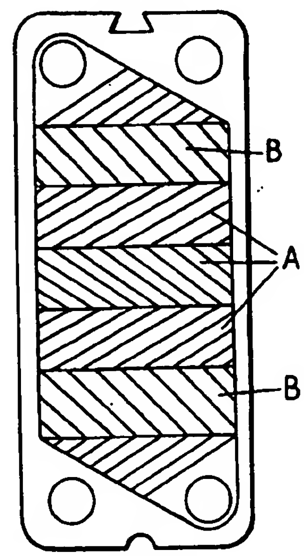


FIG.8.

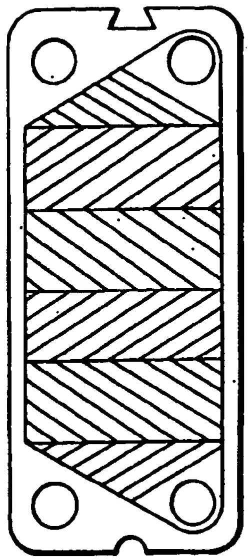


FIG.9.

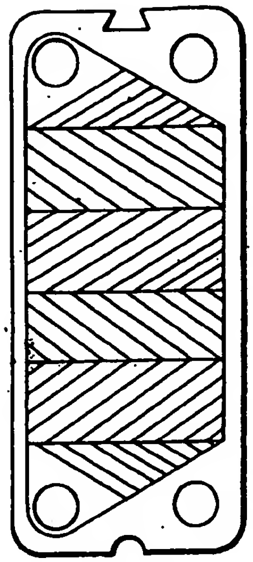


FIG.10.

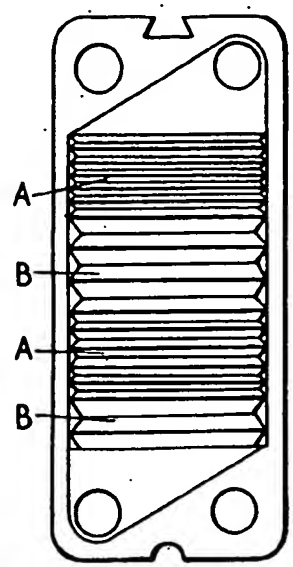


FIG.11.

FIG.12.

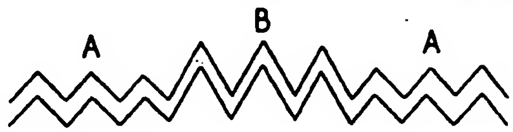


FIG.13.

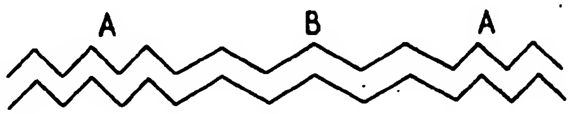
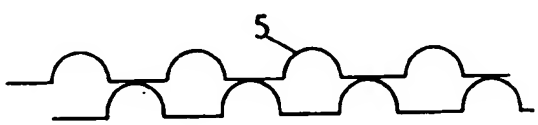


FIG.14.



1339542 PROVISIONAL SPECIFICATION
5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 4

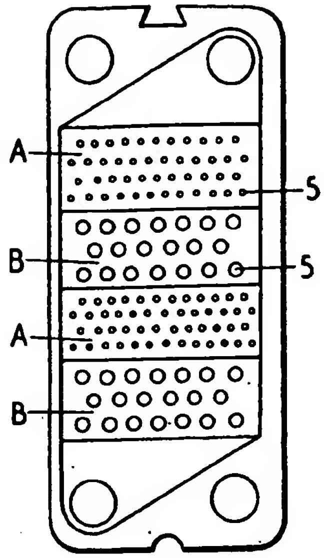


FIG.15.

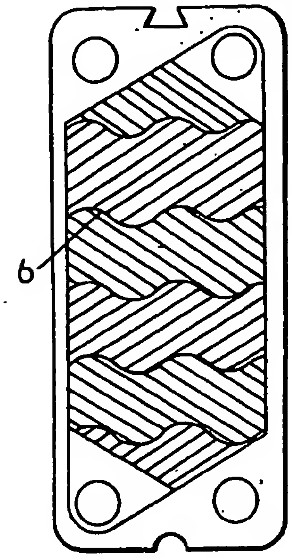


FIG.16.

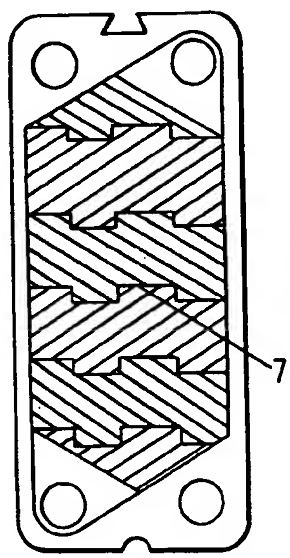


FIG.17.

1339542 PROVISIONAL SPECIFICATION
5 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 5

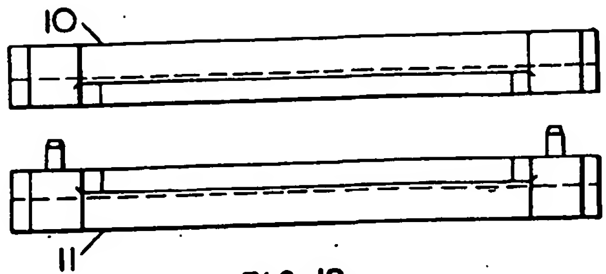


FIG.18.

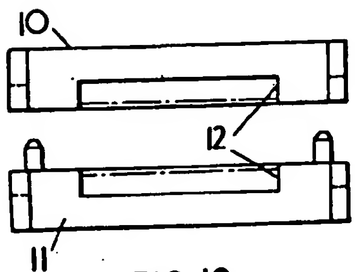


FIG.19.

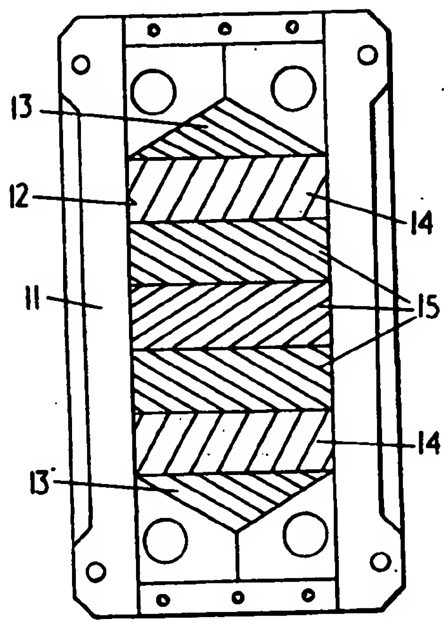


FIG.20.

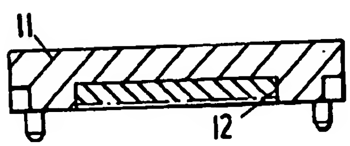


FIG.21.

1339542 COMPLETE SPECIFICATION

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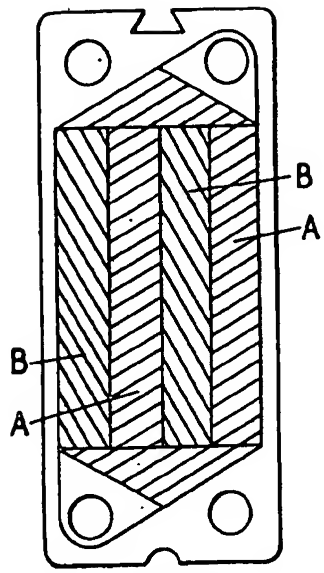

FIG. 22.

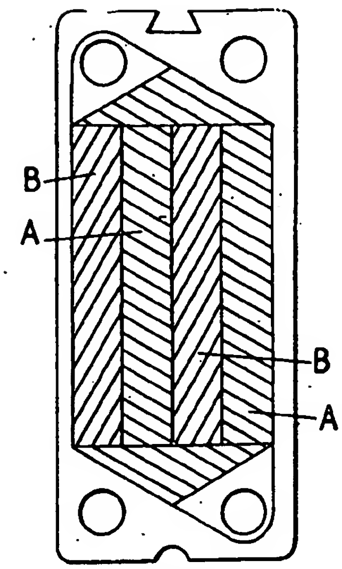

FIG. 23.

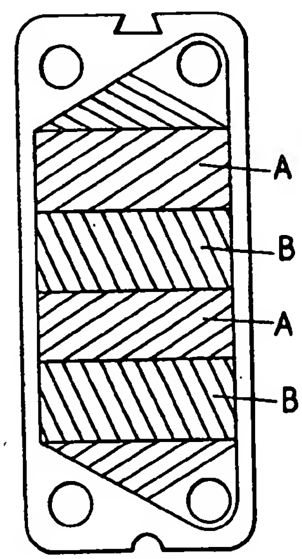

FIG. 24.

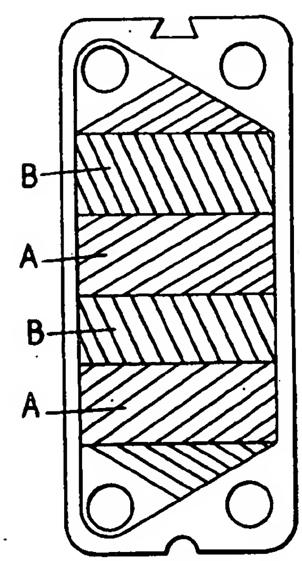

FIG. 25.